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KNORR 147 LEG V CRUISE SUMMARY: LABRADOR SEA CONVECTION EXPERIMENT

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The initial field phase of the ONR-sponsored Labrador Sea Deep Convection Experiment was successfully carried out on R/V KNORR from 2 February-20 March, 1997. The science party consisted of 19 participants from 7 institutions, comprising numerous collaborations. This report provides an overview of the different components of the cruise, and is divided into four sections corresponding to the four major programs on the ship.

Despite initial pessimism regarding the ability of a research vessel to operate in wintertime conditions in the Labrador Sea, and despite predictions of the collapse of deep convection in the region, the cruise was a remarkable success. The KNORR and her crew proved resilient to the harsh conditions encountered, and throughout our 34 working days in the region we were only hove-to about 32 hours.
1 To give an idea of the difficult working conditions, consider the following statistics for the time period over which we occupied stations, 7 Feb--12 Mar. The mean air temperature was xxC (on only one day--our last working day--did it rise above 0C, and during our closest approach to the ice-edge it was -17C). The average wind speed was xx knots (twice during the cruise we recovered the CTD package in >50 knot winds). We had only two genuinely sunny days during the five week period, and it snowed constantly, often leading to near white-out conditions (which was one of the reasons for the reduced steaming speed). One favorable factor during the cruise was that, despite the frequent passage of storms, the associated swell tended to dampen remarkably fast; this was probably the biggest reason for the limited time spent hove-to.

One of the main concerns operationally during the cruise was the tendency for icing to occur under high sea-spray conditions. The crew regularly pounded ice off of the decks and bulwarks (during one such session it was estimated that 20 tons of ice was knocked off the ship). It was a constant challenge to keep the CTD staging area free of ice and snow, and freezing of the blocks and air-tugger lines was an on-going problem. We also experienced difficulty with the float and buoy deployments because of the high sea-state and slippery conditions on deck. Despite these daily challenges, however, the crew worked diligently to keep the science program operational in some capacity, nearly full-time. Regarding the coordination of the science, because of the extent and diversity of the different measurements it was a constant challenge to keep the individual components functioning in collaborative fashion. Throughout the cruise the communication between the various groups was excellent, which was a strong reason for the overall success of the experiment. Our daily science meetings were invaluable towards the coordination of activities and overall planning.

It turns out that despite a mild December and early January, the latter part of the winter of 1996-1997 was quite robust. In fact, the atmospheric forcing during this period was strong enough to overcome the mild start, and erode through the particularly fresh surface layer of the Labrador Sea giving rise to convection down to 1500m. Thus, not only did we observe deep convection, but we did so under ``classic" wintertime conditions in the Labrador Sea. We owe this success to the very capable KNORR and her captain, and to the tremendous efforts of the crew and science party. Both the atmospheric and oceanic data sets collected are the first of their kind in this region, and will undoubtedly lead to improvements in our understanding of convection in the Labrador Sea.

Hydrography and Floats

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The hydrographic station map

(Figure 1) shows the end-result of our dual strategy to obtain basin-wide coverage, while at the same reacting to what we saw.

All stations were occupied to the bottom, and roughly half of them included sampling of CFCs (Figure 1b).2 Both the along-basin section and the southern cross-basin section were repeats of the fall HUDSON cruise, the latter being the first wintertime occupation of the WOCE AR7W line. Note that there are a total of 5 boundary crossings. On the western side we were limited by the proximity of the ice-pack, hence these sections do not extend onto the shelf. As the ice-edge was approached the ship would encounter bands of ice--including ``bergy bits" and ``growlers"--making it impossible to proceed further onshore. On our last crossing the captain made a special effort to maneuver the ship as far onshore as possible, and as a result we reached the 700 m isobath (within the core of the Labrador Current). On the eastern side, particularly on the second crossing, our biggest concern was icebergs. Despite having to divert our cruise track a couple of times we occupied two highly resolved sections across the West Greenland Current and Irminger Water.

During the course of the cruise we dropped over 140 XBTs (Figure 2). The purpose of the XBT program was two-fold. Firstly, in the interior Labrador Sea XBTs were regularly dropped between stations in order to increase spatial resolution and also alert us of any deep mixed-layers. Secondly, near the boundaries (on 3 of the 5 crossings) a high-resolution XBT section was done prior to the CTD work. The reason for this was to determine the boundary thermal structure so as to optimally place the CTD stations (thus avoiding aliasing). Both aspects of the XBT program proved crucial. Throughout the interior, the XBT profiles unambiguously provided the mixed-layer depth in near-real time (while steaming). This helped shape our CTD strategy, and directly led to our observing deep convection. On the boundaries (particularly the eastern boundary which is remarkably steep) the XBT information saved us valuable time and resources with regard to the CTD effort, and provided important small scale information to compliment the hydrography (Figure 3). It is worth noting that the cold air temperature apparently affected the performance of the XBTs. The failure rate was high for both the T-7 (800 m) and T-5 (1800 m) probes when conditions were extreme (say colder than 10 degreesC). After some tests we surmised that this was most likely due to the coating on the wire becoming damaged due to the cold. Interestingly, most of our T-7's were on the order of 10 years old, and their failure rate was higher than for the (brand new) T-5's.

While our original CTD station plan was to occupy a third complete cross-basin section, we decided instead that it would be more fruitful to re-occupy section 2 (see Figure 1a). The reasoning was as follows. First of all, it was evident that the atmospheric forcing we were experiencing was more robust than anticipated beforehand. Thus, sampling the center of the gyre late in the cruise increased our chances of actually witnessing deep convection. Secondly, the rate of mixed-layer deepening observed throughout the cruise was surprisingly rapid (and in disagreement with simple 1-D mixed-layer model predictions done onboard). It was therefore felt that a re-occupation to see the temporal evolution (while documenting the atmospheric forcing) would be enlightening. Our decision was a success on both counts (Figure 4): not only did we observe the deepest convection of the experiment, but the two occupations, separated by roughly 10 days, were strikingly different. Note, for instance, the remarkably short spatial scales during the re-occupation. We believe that active convection was taking place during this time period (or perhaps shortly before), and often the up-cast CTD profile would differ significantly from the downcast! (For example, Figure 4 is contoured with the up-cast profile of station 117; using instead the downcast profile removes the two large warm ``intrusions" near 700 m and 1200 m.) A careful analysis will be necessary to understand the observed evolution and the short scales involved. It should be remembered that we have a complete lowered acoustic doppler data set, as well as underway correlation SONAR measurements, both of which provide direct velocity information.

During the cruise we performed two detailed ``to-yo" CTD surveys (Figure 1a). The first to-yo (the northern of the two) was early in the cruise. We noticed an abnormally sharp property jump below the mixed layer in each of the CTD variables (confirmed by an XBT profile), and decided to map out its lateral variation. Presently we are still unsure as to the significance of this feature and its origin. The second to-yo was carried out near the end of the cruise (during the re-occupation of section 2). We used XBTs beforehand to ensure that at least part of this to-yo would sample deep convection. The to-yo took 36 hours to complete and consisted of five lines roughly comprising a 12 km box (Figure 5). Each line contained 3 cycles extending from the surface to 2000 m. During the to-yo we observed the deepest mixed-layer of the experiment (> 1500m) and apparently sampled the collapse of a convective feature via lateral intrusion/entrainment (see Figure 6 for a vertical and lateral view). It is envisioned that such high resolution information will help interpret some of the moored and Lagrangian data from the other components of the experiment.

Finally, the cruise served as a platform for the deployment of various drifters and floats (Table 1). No less than 7 types of Lagrangian instruments were deployed during the course of the 34 days. Upon reaching the central portion of the gyre, near the beginning of the cruise, a detailed array of RAFOS, VCM-PALACE, and Deep Lagrangian Floats were set in the midst of a detailed XBT/CTD survey (Figure 6). Throughout the rest of the cruise we deployed VCM-PALACEs (northwest portion of the domain), NSF-PALACE floats (eastern boundary), WOTAN and BAROMETER drifters (interior Labrador Sea), IFM-PALACE floats (western boundary), as well as several more RAFOS floats at selected locations. All floats (and the majority of the drifters) were deployed at CTD stations. It should be noted that conditions were too rough to deploy the floats in the standard fashion off the fantail. Instead a procedure was developed using the starboard hydro-boom in conjunction with lines and a pivot hook. This proved quite effective and enabled several float deployments in extreme winds and high sea-state.

1
It should be noted that, excluding these periods, the average steaming speed of the ship was just below 8 knots; this is >3 knots slower than under normal conditions, which did of course have an impact.

2
Selected stations also included Tritium/Helium, oxygen isotope, and carbon dioxide measurements, supported by independent funding.